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BOOT/SHOE PERFORMANCE TESTER	CHROMIC OXIDE	CHLOROFORM SOLUBLES
PROSTHETIC FOOT	pH	HIDE SUBSTANCE
ASH	PARANITROPHENOL	
UPPER LEATHER	DOW CORNING LEATHER TESTER	
INSOLE LEATHER	SHRINKAGE TEMPERATURE	

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

An evaluation of boots from 11 NATO countries was done using the new Boot/Shoe Performance Tester. This measures the boots' ability to resist water penetration. A chemical analysis of the upper leather and insole leather was also performed. All the NATO boots used high quality leather components and as expected, water repellency characteristics of the boots were more a function of design than component properties; with today's highly water-repellent leather, boot design and dynamics becomes the most prevalent factor.

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PREFACE

At the 20th Meeting of the Combat Clothing and Equipment Working Party held at NATO Headquarters in Brussels, Belgium, the United States reported on the design, development and fabrication of a Boot/Shoe Performance Tester (Project #1G464713DL40) which simulates the normal foot and leg movements associated with walking at a rate of one to four miles per hour (1.6 to 6.4 km per hour).

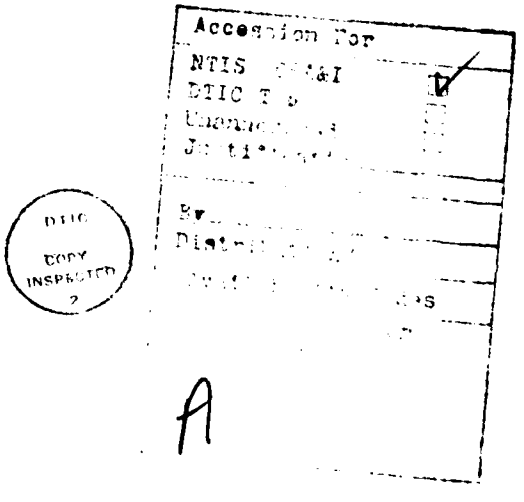
The United States offered to evaluate boots from each of the NATO countries and to submit a report on this evaluation at the next meeting of the Working Party.

The objective of this report is to present the results of a comparative laboratory evaluation of standard Military Combat Boots received from various NATO countries using the Boot/Shoe Performance Tester developed in the Individual Protection Laboratory at the Natick Research & Development Command.

The authors wish to thank the various NATO countries for providing the boots used to perform this evaluation.

In addition the authors would like to express their sincere gratitude to Mr. Leonard Campbell, Chief, Clothing Branch and to Mr. Douglas S. Swain, Chief, Equipment and Footwear Group for the interest and guidance provided during this study.

The enthusiastic assistance provided by Mr. Mark Santos in performing the chemical evaluations is also gratefully acknowledged.



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EVALUATION OF MILITARY COMBAT BOOTS FROM NATO COUNTRIES

INTRODUCTION

Evaluation of the various NATO boots was initiated after implementation of trials with the Boot/Shoe Performance Tester. At this time it was also decided to do a chemical analysis of the leather used in each boot (upper and sole leather) for additional comparative purposes. A total of 14 types of boots representing 11 NATO countries were included in this evaluation. Socks that were submitted were worn on the prosthetic foot during the testing on the Boot/Shoe Performance Tester. If more than one kind was included, the lighter of the two types was used. If no socks were submitted, the standard United States Military Wool Socks (MIL–S–48J) were used.[1]

All experiments were performed in a humidity and temperature controlled environment. All items were allowed to reach equilibrium status with the controlled environment of 50 percent relative humidity and a temperature of 23 ± 2° Celsius prior to evaluation. These are standard conditions used to test leather in the United States.[2]

An item description is provided for each type of boot in order to present the more obvious design features inherent in that item.

The cattlehide leather specification for combat boot leather MIL–L–3122F was used as the guide in the chemical analysis.[3] The test methods used for the chemical analysis are listed in Federal Test Method Standard No. 311 entitled "Leather, Methods of Sampling and Testing."[4] The identification number and title of each test method used are listed in Table 1. In preparation for the chemical tests, sections were taken from the upper and insole areas of one boot from each type and subsequently cut into pieces approximately 13-mm square. These pieces were then ground in a Wiley Mill until all the material passed through a 4-mm sieve.

[1] Military Specification MIL–S–48J, Socks, Men's Wool, Cushion Sole, Stretch Type (27 April 1978)

[2] Federal Test Method Standard No. 311, Leather, Methods of Sampling and Testing (24 January 1975)

[3] Military Specification MIL–L–3122F, Leather, Cattlehide, for Footwear Uppers, Chrome Tanned, Fat Liquored (10 September 1975)

[4] See reference 2.

Table 1. Test Methods Used

Title	FTMS Number
Shrinkage Temperature	7011.1
Moisture Content, Oven Method	6221
Chloroform Soluble and Water Soluble Materials, and Insoluble Inorganic Materials	6341
Nitrogen, Collagenous and Hide Substance	6441
Chromic Oxide, Perchloric Acid Method	6515
Ash (Insoluble Inorganic Materials)	6341
pH Value of Leather	6621.1
Paranitrophenol, Colorimetric Method	6711
Dynamic Water Resistance Test (Dow Corning Leather Tester)	8131.1

EXPLANATION OF TESTS

Shrinkage Temperature – Provides indication of relative chrome content.

Moisture Content – Percent of water in leather; basically required in calculations in the other tests.

Chloroform Extraction and Paranitrophenol Analysis – The extraction provides a measure of the percent of chloroform soluble material (organic, non-proteinaceous substances). The extract can then be used to determine the percent of paranitrophenol in the leather.

Nitrogen, Collagenous and Hide Substance – Gives an estimate of the percent of protein in the leather and therefore, how much chemical and filler was added during the tanning process.

Ash and Chromic Oxide – The Ash Test is a determination for the percent of inorganic material in the leather. The chromic oxide analysis is a measure of what percent of the ash is chrome, which was used in tanning.

pH Value of Leather – Determines the stability of the chrome collagen complex induced in tanning.

The level of water resistance of the upper leather was measured with the Dow Corning Leather Tester. When sufficient leather was available, a 90-mm x 100-mm sample was cut from the leg-ankle area of the boot to be evaluated. The 90-mm dimension was folded in half and the edge of this fold was glued to produce a pocket shape. The folded ends were placed in the clamps of the Dow Corning Tester. This pocket was loaded with 100 grams of conductive stainless steel balls and a detecting electrode was immersed into the conductive media. The outside of the leather pocket was immersed in water and the flexer operated

at 60 flexes per minute. When water penetrated through the leather in sufficient quantity to reduce the resistance in the electrical circuit to 7500 ohms, the counter stopped and the number of flexes required for water penetration was recorded.

After the initial test for resistance to water penetration, the leather samples were thoroughly dried and treated with a dilute solution of Dow Corning water-resistant-resin-treatment for leather called DC—477. The samples were then air dried, cured and retested on the Dow Corning Leather Tester, as previously described.

Boot/Shoe Performance Tester: Figure 1 is a photograph of the Boot/Shoe Performance Tester. It is provided to illustrate the design and operating principles of this machine. It simulates the normal foot and leg movements associated with walking at a rate of one to four miles per hour (1.6 to 6.4 km per hour). The downward force exerted by the leg/foot section is adjustable from 100 to 200 pounds (450 to 900 kg) to simulate the walking thrust that is produced by individuals in varying weight classifications. The motion of the artifical foot (size 10D) approximates the flexibility and expansion characteristics of a human foot when walking under the weight of the body and equipment. Figure 2 shows a typical prosthetic foot with coiled stainless steel moisture detecting sensors.

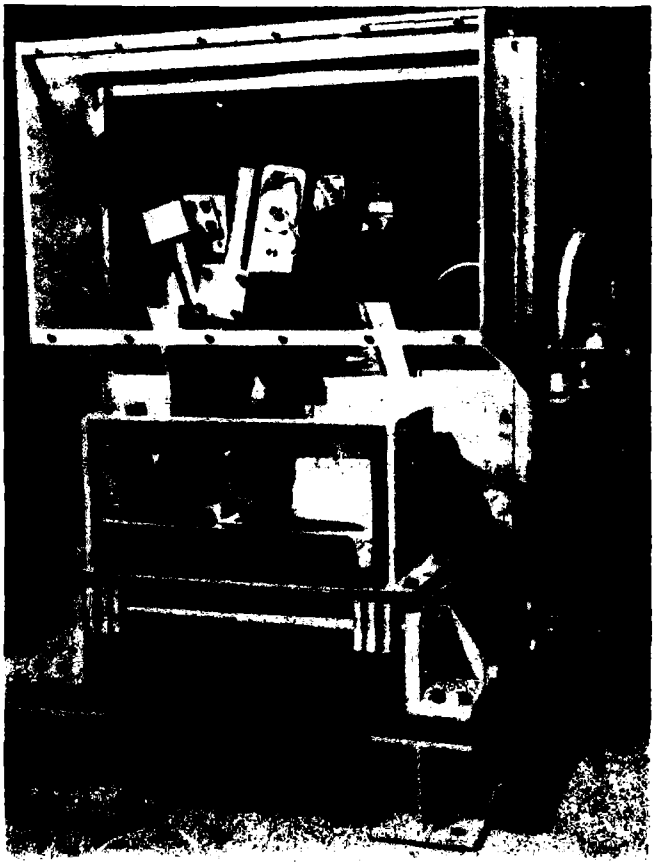

Figure 1. Boot/Shoe Performance Tester

Figure 2. Prosthetic Foot

The moisture detecting sensors are located at the metatarsal (big toe), inner and outer ball (flex area), inner and outer heel, and instep areas. As each sensor detects moisture its associated counter ceases tabulating and denotes the number of steps that were required for the boot to leak at that location.

The corresponding sock and boot from each NATO country were placed on the prosthetic foot and the machine adjusted so that it operated at 35 steps per minute with a downward thrust of 100 pounds (450 kg). A one percent solution of sodium chloride in deionized water was used to immerse the boot to a depth of 5 cm at the start of the test. Each boot was walked on the Boot/Shoe Performance Tester until all sensors indicated the presence of water in the various boot sections.

In all, 14 boots from 11 NATO countries were submitted for evaluation. The countries represented are:

Belgium

Canada

Denmark

England

France

Germany

Greece

Italy

Netherlands

Norway

United States

The design features inherent in the boots evaluated in this report are shown in the photographs identified as Figures 3 to 16.

Tables 2 to 15 contain the data obtained from the chemical analysis of the upper leathers and insoles taken from the various NATO boots.

Table 16 is a listing of the summary data gathered during the chemical analysis of the upper leathers.

Table 17 is a listing of the summary data gathered during the chemical analysis of the insoles.

Table 18 is a summary of the number of steps required on the Boot/Shoe Performance Tester for water to penetrate through the various boots.

ITEM DESCRIPTION

Belgian Boot

Design and Method of Boot Construction: Black plain toe welt constructed boot with traction lugged rubber sole and heel and exterior counter pocket with straight backstay.

Height: 27 cm

Weight: 925 g per boot

Color and Appearance of Leather: Corrected grain black upper leather with embossed course hair cell or pebble print.

Type of Lining: None

Description of Lacing System: Black flat laces and 9 pairs of black round metal eyelets.

Description of Outsole and Heel: Rubber lugged sole stitched to welting and rubber lugged heel attached with twelve nails.

Comments: Figure 3 shows the sock worn with Belgian Boot. However, it does not show Belgian Boot because this item was destroyed in testing prior to the taking of photographs.

Figure 3. Sock Accompanying Belgian Boot

Table 2. Evaluation of Belgian Boot

Chemical Properties	Upper Leather	Insole Leather
Shrinkage Temperature, degree Celsius	>98.00	--
Moisture content, percent	13.30	12.00
Chloroform soluble matter, percent	15.40	8.16
Nitrogen content, percent	12.40	8.29
Hide substance, percent	69.80	46.60
Chromic oxide, hide substance basis, percent	4.56	0.00
Ash, percent	6.18	1.05
pH	3.59	5.12
Paranitrophenol, percent	0.00	0.00

Number of flexes necessary for penetration of water through a sample of upper leather on the Dow Corning Water Penetration Tester.

As is,	255 flexes
After Silicone Treatment	450 flexes

Boot/Shoe Performance Tester Results

Locations Observed	Number of steps for penetration in 5 cm of water at 35 steps/minute
Instep	400
Inner Ball	260
Big Toe	200
Outer Ball	400
Outer Heel	300
Inner Heel	240

ITEM DESCRIPTION

Canadian Boot

Design and Method of Boot Construction: One piece long vamp with bellows backstay and no outside counter pocket. Vulcanized sole and heel.

Height: 26 cm

Weight: 1012 g per boot

Color and Appearance of Leather: Corrected grain black upper leather with embossed pebble print.

Type of Lining: Full cattlehide glove leather lining.

Description of Lacing System: Black round lace and 9 pairs of black round metal eyelets. V–groove cut in leather between fourth and fifth row of eyelets.

Description of Outsole and Heel: One piece vulcanized Z–bar traction design sole and heel. Rubber sole and heel molded and cured directly onto bottom of boot.

Comments: Figure 4 illustrates sock and Canadian Boot evaluated.

Figure 4. Canadian Boot

Table 3. Evaluation of Canadian Boot

Chemical Properties	Upper Leather	Insole Leather
Shrinkage Temperature, degrees Celsius	98.00	--
Moisture content, percent	11.40	11.10
Chloroform soluble matter, percent	12.50	9.70
Nitrogen content, percent	12.70	6.12
Hide substance, percent	71.30	34.40
Chromic oxide, hide substance basis, percent	3.13	2.16
Ash, percent	5.31	10.30
pH	3.15	3.21
Paranitrophenol, percent	0.20	0.23

Number of flexes necessary for penetration of water through a sample of upper leather on the Dow Corning Water Penetration Tester.

As is,	89 flexes
After Silicone Treatment	441 flexes

Boot/Shoe Performance Tester Results

Locations Observed	Number of steps for penetration in 5 cm of water at 35 steps/minute
Instep	700
Inner Ball	337
Big Toe	404
Outer Ball	850
Outer Heel	583
Inner Heel	600

ITEM DESCRIPTION

Danish Boot

Design and Method of Boot Construction: Black vamp-blucher welt construction with leather toe cap and exterior counter pocket and straight backstay, welting and midsole stitched to upper.

Height: 27 cm

Weight: 965 g per boot

Color and Appearance of Leather: Corrected grain black upper leather with embossed pebble print.

Type of Lining: None

Description of Lacing System: Black flat lace and 4 pairs of black round metal eyelets at bottom of boot and 6 rows of open hooks followed by one row of metal eyelets at top of boot.

Description of Outsole and Heel: The premolded rubber lugged sole and heel is cemented to midsole and reinforced with the following:

9 brass screws in shank area
4 brass screws in toe area
3 nails in outer heel area

Comments: Figure 5 illustrates Danish Boot evaluated.

Figure 5. Danish Boot

Table 4. Evaluation of Danish Boot

Chemical Properties	Upper Leather	Insole Leather
Shrinkage Temperature, degree Celsius	>98.00	--
Moisture content, percent	11.90	10.70
Chloroform soluble matter, percent	14.40	6.93
Nitrogen content, percent	12.80	9.53
Hide substance, percent	71.90	53.60
Chromic oxide, hide substance basis, percent	5.36	0.00
Ash, percent	5.50	1.84
pH	3.33	4.58
Paranitrophenol, percent	0.00	0.00

Number of flexes necessary for penetration of water through a sample of upper leather on the Dow Corning Water Penetration Tester.

As is,	3230 flexes
After Silicone Treatment	7332 flexes

Boot/Shoe Performance Tester Results

Locations Observed	Number of steps for penetration in 5 cm of water at 35 steps/minute
Instep	1005
Inner Ball	23
Big Toe	23
Outer Ball	34
Outer Heel	441
Inner Heel	157

ITEM DESCRIPTION

English Boot
(Low Cut)

Design and Method of Boot Construction: Low cut black boot in vamp-blucher construction, leather toe cap, and one-piece exterior counter pocket and backstay. Injection molded lug sole and heel. Boot contained a saran ventilating insole with a thin piece of leather stitched to the top surface of the insole.

Height: 18 cm

Weight: 800 g per boot

Color and Appearance of Leather: Black, slightly corrected grain, upper leather in toe and counter area. Remaining portion of boot has upper leather with embossed pebble print. Leather in toe and counter area designed for good shinability.

Type of Lining: None

Description of Lacing System: Black round lace and 6 pairs of black round metal eyelets.

Description of Outsole and Heel: Injection-molded, traction-lugged sole and heel.

Comments: Figure 6 illustrates English Boot evaluated.

Figure 6. English Boot (Low Cut)

Table 5. Evaluation of English Boot (Low Cut)

Chemical Properties	Upper Leather	Insole Leather
Shrinkage Temperature, degrees Celsius	>98.00	--
Moisture content, percent	11.90	9.53
Chloroform soluble matter, percent	8.51	11.90
Nitrogen content, percent	13.30	13.00
Hide substance, percent	74.80	72.80
Chromic oxide, hide substance basis, percent	4.56	1.58
Ash, percent	5.50	3.37
pH	3.39	3.49
Paranitrophenol, percent	0.00	0.00

Number of flexes necessary for penetration of water through a sample of upper leather on the Dow Corning Water Penetration Tester.

As is,
After Silicone Treatment*

Boot/Shoe Performance Tester Results

Locations Observed	Number of steps for penetration in 5 cm of water at 35 steps/minute
Instep	319
Inner Ball	102
Big Toe	140
Outer Ball	20
Outer Heel	107
Inner Heel	50

*Boot not large enough to provide sample for this test.

ITEM DESCRIPTION

English Boot

(High Cut)

Design and Method of Boot Construction: Back, plain toe vamp – blucher construction with one-piece, wrap-around counter pocket and backstay. Injection-molded sole and heel with molded bead in welting area. Boot contained a saran ventilating insole with a thin piece of leather stitched to the top surface of the insole. Pull tab at rear of boot for easy donning.

Height: 27 cm

Weight: 932 g per boot

Color and Appearance of Leather: Corrected grain, black upper leather with fine hair cell print similar to full grain leather.

Type of Lining: None

Description of Lacing System: Black, flat lace and 10 pairs of black round metal eyelets.

Description of Outsole and Heel: One-piece, injection-molded Z-bar traction design sole and heel. Rubber sole and heel molded and cured directly onto bottom of boot.

Comments: Figure 7 illustrates sock and English Boot evaluated.

Figure 7. English Boot (High Cut)

Table 6. Evaluation of English Boot (High Cut)

Chemical Properties	Upper Leather	Insole Leather
Shrinkage Temperature, degrees Celsius	98.00	---
Moisture content, percent	12.50	10.20
Coloroform soluble matter, percent	9.75	11.50
Nitrogen content, percent	13.70	9.72
Hide substance, percent	77.00	54.60
Chromic oxide, hide substance basis, percent	4.51	1.43
Ash, percent	6.64	3.28
pH	3.95	3.56
Paranitrophenol, percent	0.00	0.00

Number of flexes necessary for penetration of water through a sample of upper leather on the Dow Corning Water Penetration Tester.

As is,
After Silicone Treatment*

Boot/Shoe Performance Tester Results

Locations Observed	Number of steps for penetration in 5 cm of water at 35 steps/minute
Instep	296
Inner Ball	805
Big Toe	975
Outer Ball	914
Outer Heel	139
Inner Heel	159

*Boot not large enough to provide sample for this test.

ITEM DESCRIPTION

French Boot

Design and Method of Boot Construction: Black plain toe vamp – blucher welt construction with exterior counter pocket and straight backstay. Welting and midsole stitched to upper.

Height: 28 cm

Weight: 1020 g per boot

Color and Appearance of Leather: Corrected grain black upper leather with embossed pebble print.

Type of Lining: Tan, vegetable-tanned leather lining in vamp area. Brown, vegetable-tanned leather lining in remainder of boot.

Description of Lacing System: Black flat lace and 8 pairs of black round metal eyelets and a 4-inch-wide crossover support strap secured with two metal buckles at top of boot.

Description of Outsole and Heel: Premolded rubber lugged sole and heel. Sole cemented to midsole of boot. Heel cemented and nailed to sole with 8 nails.

Comments: Figure 8 illustrates the sock and French Boot evaluated.

Figure 8. French Boot

Table 7. Evaluation of French Boot

Chemical Properties	Upper Leather	Insole Leather
Shrinkage Temperature, degrees Celsius	>98.00	---
Moisture content, percent	9.76	9.92
Chloroform soluble matter, percent	21.80	10.91
Nitrogen content, percent	8.48	7.62
Hide substance, percent	47.70	42.80
Chromic oxide, hide substance basis, percent	2.34	0.38
Ash, percent	3.69	2.52
pH	3.75	3.95
Paranitrophenol, percent	0.00	0.00

Number of flexes necessary for penetration of water through a sample of upper leather on the Dow Corning Water Penetration Tester.

As is,	73 flexes
After Silicone Treatment	634 flexes

Boot/Shoe Performance Tester Results

Locations Observed	Number of steps for penetration in 5 cm of water at 35 steps/minute
Instep	349
Inner Ball	1
Big Toe	28
Outer Ball	50
Outer Heel	253
Inner Heel	16

ITEM DESCRIPTION

German Ski Boot

Design and Method of Boot Construction: Black vamp – blucher welt construction with leather toe cap and exterior counter pocket and straight backstay. Welting and midsole stitched to upper.

Height: 28 cm

Weight: 952 g per boot

Color and Appearance of Leather: Corrected grain black upper leather with embossed pebble print.

Type of Lining: None

Description of Lacing System: Black flat lace and 4 pairs of black round metal eyelets at bottom of boot and 6 rows of open hooks followed by one row of round metal eyelets at top of boot.

Description of Outsole and Heel: The premolded rubber lugged sole and heel is cemented to midsole and reinforced with the following:

9 brass screws in shank area
3 nails in outer heel area

Comments: Figure 9 illustrates the sock and German Ski Boot evaluated.

Figure 9. German Ski Boot

Table 8. Evaluation of German Ski Boot

Chemical Properties	Upper Leather	Insole Leather
Shrinkage Temperature, degrees Celsius	96.00	---
Moisture content, percent	14.73	14.20
Chloroform soluble matter, percent	15.52	3.83
Nitrogen content, percent	11.39	10.68
Hide substance, percent	64.01	60.05
Chromic oxide, hide substance basis, percent	2.96	0.00
Ash, percent	3.65	1.62
pH	4.26	4.94
Paranitrophenol, percent	0.00	0.00

Number of flexes necessary for penetration of water through a sample of upper leather on the Dow Corning Water Penetration Tester.

As is,	641 flexes
After Silicone Treatment	2744 flexes

Boot/Shoe Performance Tester Results

Location Observed	Number of steps for penetration in 5 cm of water at 35 steps/minute
Instep	2088
Inner Ball	396
Big Toe	140
Outer Ball	1101
Outer Heel	2078
Inner Heel	444

ITEM DESCRIPTION

German Combat Boot

Design and Method of Boot Construction: Brown, plain toe vamp – blucher welt construction with exterior counter pocket. Heavy storm welting and midsole is stitched to upper. Welting stitch is coated with wax for water repellancy. Pull tab at rear of boot for easy donning.

Height: 26 cm

Weight: 1019 g per boot

Color and Appearance of Leather: Brown, full-grain upper leather with light application of finish for uniform appearance.

Type of Lining: None

Description of Lacing System: Round brown lace and 9 pairs of closed speed lacing loops.

Description of Outsole and Heel: Premolded brown lugged sole and heel. Sole cemented to midsole. Heel attached by cement and reinforced with eight nails.

Comments: Figure 10 illustrates the sock and German Combat Boot evaluated.

Figure 10. German Combat Boot

Table 9. Evaluation of German Combat Boot

Chemical Properties	Upper Leather	Insole Leather
Shrinkage Temperature, degrees Celsius	>98.00	—
Moisture content, percent	12.60	10.40
Chloroform soluble matter, percent	18.00	10.30
Nitrogen content, percent	11.10	9.88
Hide substance, percent	62.60	55.50
Chromic oxide, hide substance basis, percent	4.09	.29
Ash, percent	7.36	1.52
pH	3.97	4.18
Paranitrophenol, percent	0.00	0.00

Number of flexes necessary for penetration of water through a sample of upper leather on the Dow Corning Water Penetration Tester.

As is,	10 645 flexes
After Silicone Treatment	27,339 flexes

Boot/Shoe Performance Tester Results

Location Observed	Number of steps for penetration in 5 cm of water at 35 steps/minute
Instep	1495
Inner Ball	51
Big Toe	99
Outer Ball	101
Outer Heel	179
Inner Heel	33

ITEM DESCRIPTION

Greek Boot

Design and Method of Boot Construction: Black plain toe vamp—blucher construction with exterior counter pocket and bellows backstay. Vulcanized sole and heel with chevron design. Boot contained a polypropylene ventilating insole.

Height: 26 cm

Weight: 894 g per boot

Color and Appearance of Leather: Full-grain black upper leather.

Type of Lining: Cloth lining in vamp area.

Description of Lacing System: Black round lace and 9 pairs of black round metal eyelets.

Description of Outsole and Heel: Vulcanized chevron design on outsole and heel. Rubber sole and heel molded and cured directly onto bottom of boot.

Comments: Figure 11 illustrates Greek Boot evaluated.

Figure 11. Greek Boot

Table 10. Evaluation of Greek Boot

Chemical Properties	Upper Leather	Insole Leather
Shrinkage Temperature, degrees Celsius	98.00	—
Moisture content, percent	12.70	10.80
Chloroform soluble matter, percent	12.10	4.76
Nitrogen content, percent	13.80	7.53
Hide substance, percent	77.30	42.30
Chromic oxide, hide substance basis, percent	4.47	1.30
Ash, percent	5.02	8.56
pH	3.62	2.95
Paranitrophenol, percent	0.00	0.00

Number of flexes necessary for penetration of water through a sample of upper leather on the Dow Corning Water Penetration Tester.

As is,	6,127 flexes
After Silicone Treatment	12,226 flexes

Boot/Shoe Performance Tester Results

Locations Observed	Number of steps for penetration in 5 cm of water at 35 steps/minute
Instep	83
Inner Ball	55
Big Toe	49
Outer Ball	66
Outer Heel	10
Inner Heel	1500

ITEM DESCRIPTION

Italian Boot

Design and Method of Boot Construction: Brown, vamp – blucher welt construction with leather toe cap and exterior wrap-around counter pocket and straight backstay. Two rows of stitching through storm welting.

Height: 27 cm

Weight: 1035 g per boot

Color and Appearance of Leather: Brown, full-grain upper leather with light application of finish for uniform appearance.

Type of Lining: None

Description of Lacing System: Brown flat lace and 6 pairs of round metal eyelets and a 4-inch wide crossover support strap secured with two metal buckles at top of boot.

Description of Outsole and Heel: Premolded rubber-imitation, vibram sole and heel. Sole stitched through midsole and welting. Toe area reinforced with six brass screws. Heel cemented and nailed to sole with 10 nails.

Comments: Figure 12 illustrates the sock and Italian Boot evaluated.

Figure 12. Italian Boot

Table 11. Evaluation of Italian Boot

Chemical Properties	Upper Leather	Insole Leather
Shrinkage Temperature, degrees Celsius	>98.00	---
Moisture content, percent	14.00	8.76
Chloroform soluble matter, percent	8.27	8.31
Nitrogen content, percent	13.50	7.40
Hide substance, percent	75.80	41.60
Chromic oxide, hide substance basis, percent	5.11	0.00
Ash, percent	5.56	4.28
pH	3.53	4.11
Paranitrophenol, percent	0.00	0.00

Number of flexes necessary for penetration of water through a sample of upper leather on the Dow Corning Water Penetration Tester.

As is,	558 flexes
After Silicone Treatment	2974 flexes

Boot/Shoe Performance Tester Results

Locations Observed	Number of steps for penetration in 5 cm of water at 35 steps/minute
Instep	810
Inner Ball	195
Big Toe	880
Outer Ball	591
Outer Heel	489
Inner Heel	847

ITEM DESCRIPTION

Netherlands Boot

Design and Method of Boot Construction: One-piece, long-vamp construction with straight backstay and no outside counter pocket. Injection molded sole and heel.

Height: 25 cm

Weight: 1012 g per boot

Color and Appearance of Leather: Brown, full-grain upper leather with light application of finish for uniform appearance.

Type of Lining: Full cattlehide glove leather lining.

Description of Lacing System: Round brown lace and 8 pairs of closed speed lacing loops.

Description of Outsole and Heel: Traction bar design injection molded sole and heel.

Comments: Figure 13 illustrates the sock and Netherlands Boot evaluated.

Figure 13. Netherlands Boot

Table 12. Evaluation of Netherlands Boot

Chemical Properties	Upper Leather	Insole Leather
Shrinkage Temperature, degrees Celsius	>98.00	—
Moisture content, percent	11.40	10.57
Chloroform soluble matter, percent	16.00	4.51
Nitrogen content, percent	12.00	8.17
Hide substance, percent	67.70	45.90
Chromic oxide, hide substance basis, percent	4.30	0.00
Ash, percent	5.93	3.05
pH	3.65	3.36
Paranitrophenol, percent	0.00	0.00

Number of flexes necessary for penetration of water through a sample of upper leather on the Dow Corning Water Penetration Tester.

As is,	7,800 flexes
After Silicone Treatment	6,365 flexes

Boot/Shoe Performance Tester Results

Locations Observed	Number of steps for penetration in 5 cm of water at 35 steps/minute
Instep	90
Inner Ball	1200
Big Toe	590
Outer Ball	760
Outer Heel	3000
Inner Heel	2100

ITEM DESCRIPTION

Norwegian Boot

(Low Cut)

Design and Method of Boot Construction: Low cut black boot in vamp – blucher design with exterior counter pocket and straight backstay. Injection molded sole and heel.

Height: 17 cm

Weight: 797 g per boot

Color and Appearance of Leather: Corrected grain, black upper leather with embossed pebble print.

Type of Lining: None

Description of Lacing System: Black flat lace and 6 pairs of black round metal eyelets.

Description of Outsole and Heel: Injection molded outsole and heel, outsole and heel modified chevron design.

Comments: Figure 14 illustrates the socks and Norwegian Boot evaluated.

Figure 14. Norwegian Boot (Low Cut)

Table 13. Evaluation of Norweigian Boot (Low Cut)

Chemical Properties	Upper Leather	Insole Leather
Shrinkage Temperature, degrees Celsius	>98.00	--
Moisture content, percent	12.40	10.10
Chloroform soluble matter, percent	12.20	5.06
Nitrogen content, percent	12.70	9.43
Hide substance, percent	71.20	53.00
Chromic oxide, hide substance basis, percent	5.35	0.00
Ash, percent	7.00	4.31
pH	3.65	3.72
Paranitrophenol, percent	0.00	0.00

Number of flexes necessary for penetration of water through a sample of upper leather on the Dow Corning Water Penetration Tester.

	As is, After Silicone Treatment*

Boot/Shoe Performance Tester Results

Locations Observed	Number of steps for penetration in 5 cm of water at 35 steps/minute
Instep	951
Inner Ball	42
Big Toe	974
Outer Ball	530
Outer Heel	20
Inner Heel	326

*Boot not large enough to provide sample for this test.

ITEM DESCRIPTION

Norwegian Boot

(High Cut)

Design and Method of Boot Construction: Black plain toe vamp – blucher construction with exterior counter pocket and straight backstay. Injection molded sole and heel.

Height: 26 cm

Weight: 885 g per boot

Color and Appearance of Leather: Corrected grain, black upper leather with embossed pebble print.

Type of Lining: None

Description of Lacing System: Black flat lace with 4 pairs of closed D-ring and 4 pairs of open lace hooks.

Description of Outsole and Heel: Injection molded outsole and heel in modified chevron design.

Comments: Figure 15 illustrates socks and Norwegian Boot evaluated.

Figure 15. Norwegian Boot (High Cut)

Table 14. Evaluation of Norwegian Boot (High Cut)

Chemical Properties	Upper Leather	Insole Leather
Shrinkage Temperature, degrees Celsius	>98.00	---
Moisture content, percent	11.80	10.00
Chloroform soluble matter, percent	14.40	6.00
Nitrogen content, percent	12.30	9.65
Hide substance, percent	68.90	54.20
Chromic oxide, hide substance basis, percent	5.22	0.00
Ash, percent	7.20	3.08
pH	3.77	3.55
Paranitrophenol, percent	0.00	0.00

Number of flexes necessary for penetration of water through a sample of upper leather on the Dow Corning Water Penetration Tester.

As is,
After Silicone Treatment*

Boot/Shoe Performance Tester Results

Locations Observed	Number of steps for penetration in 5 cm of water at 35 steps/minute
Instep	307
Inner Ball	206
Big Toe	265
Outer Ball	160
Outer Heel	884
Inner Heel	882

*Boot not large enough to provide sample for this test.

ITEM DESCRIPTION

American Boot

Design and Method of Boot Construction: Black, plain toe vamp – blucher construction with exterior counter pocket and bellows backstay. Vulcanized sole and heel with chevron design. Boot contained a saran ventilating insole.

Height: 25 cm

Weight: 780 g per boot

Color and Appearance of Leather: Full-grain, black upper leather.

Type of Lining: Cloth lining in vamp area.

Description of Lacing System: Black, round lace and 9 pairs of black round metal eyelets. V-groove cut in leather between fourth and fifth row of eyelets.

Description of Outsole and Heel: Vulcanized chevron design on outsole and heel. Rubber sole and heel molded and cured directly onto bottom of boot.

Comments: Figure 16 illustrated sock and American Boot evaluated.

Figure 16. American Boot

Table 15. Evaluation of American Boot

Chemical Properties	Upper Leather	Insole Leather
Shrinkage Temperature, degrees Celsius	>98.00	---
Moisture content, percent	13.20	11.40
Chloroform soluble matter, percent	9.76	5.73
Nitrogen content, percent	12.60	6.98
Hide substance, percent	71.00	39.20
Chromic oxide, hide substance basis, percent	4.89	1.94
Ash, percent	6.06	10.70
pH	3.61	3.46
Paranitrophenol, percent	0.31	0.30

Number of flexes necessary for penetration of water through a sample of upper leather on the Dow Corning Water Penetration Tester.

As is,	165 flexes
After Silicone Treatment	313 flexes

Boot/Shoe Performance Tester Results

Locations Observed	Number of steps for penetration in 5 cm of water at 35 steps/minute
Instep	648
Inner Ball	781
Big Toe	337
Outer Ball	635
Outer Heel	781
Inner Heel	415

Table 16. Upper Leather Summary Table

UPPER LEATHER CHEMICAL PROPERTY	Belgian Boot	Canadian Boot	Danish Boot	French Boot	German Ski Boot	German Combat Boot	Greek Boot	Italian Boot	Netherlands Boot	Norwegian Boot (Low Cut)	Norwegian Boot (High Cut)	English Boot (Low Cut)	English Boot (High Cut)	American Boot
Shrinkage Temperature (°C)	>98.00	98.00	>98.00	>98.00	96.00	>98.00	98.00	>98.00	>98.00	>98.00	>98.00	>98.00	98.00	>98.00
Moisture Content (%)	13.30	11.40	11.90	9.76	14.73	12.60	12.70	14.00	11.40	12.40	11.80	11.90	12.50	13.20
Chloroform Soluble Matter (%)	15.40	12.50	14.40	21.80	15.52	18.00	12.10	8.27	16.00	12.20	14.40	8.51	9.75	9.76
Nitrogen Content (%)	12.40	12.70	12.80	8.48	11.39	11.10	13.80	13.50	12.00	12.70	12.30	13.30	13.70	12.60
Hide Substance (%)	69.80	71.30	71.90	47.70	64.01	62.60	77.30	75.80	67.70	71.20	68.90	74.80	77.00	71.00
Chromic Oxide (%)	4.56	3.13	5.36	2.34	2.96	4.09	4.47	5.11	4.30	5.35	5.22	4.56	4.51	4.89
Ash (%)	6.18	5.31	5.50	3.69	3.65	7.36	5.02	5.56	5.93	7.00	7.20	5.50	6.64	6.06
pH	3.59	3.15	3.33	3.75	4.26	3.97	3.62	3.53	3.65	3.65	3.77	3.39	3.95	3.61
Paranitrophenol Content (%)	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31
Dow Corning Flex Test	255	89	3230	73	641	10645	6127	558	7800	–	–	–	–	165
Dow Coring Flex Test (w/Silicone)	450	441	7332	634	2744	27339	12226	2974	6365	–	–	–	–	313

Table 17. Sole Leather Summary Table

SOLE LEATHER CHEMICAL PROPERTY	Belgian Boot	Canadian Boot	Danish Boot	French Boot	German Ski Boot	German Combat Boot	Greek Boot	Italian Boot	Netherlands Boot	Norwegian Boot (Low Cut)	Norwegian Boot (High Cut)	English Boot (Low Cut)	English Boot (High Cut)	American Boot
Shrinkage Temperature (°C)	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Moisture Content (%)	12.00	11.10	10.70	9.92	14.20	10.40	10.80	8.76	10.57	10.10	10.00	9.53	10.20	11.40
Chloroform Soluble Matter(%)	8.16	9.70	6.93	10.91	3.83	10.30	4.76	8.31	4.51	5.06	6.00	11.90	11.50	5.73
Nitrogen Content (%)	8.29	6.12	9.53	7.62	10.68	9.88	7.53	7.40	8.17	9.43	9.65	13.00	9.72	6.98
Hide Substance (%)	46.60	34.40	53.60	42.80	60.05	55.50	42.30	41.60	45.90	53.00	54.20	72.80	54.60	39.20
Chromic Oxide (%)	0.00	2.16	0.00	0.38	0.00	0.29	1.30	0.00	0.00	0.00	0.00	1.58	1.43	1.94
Ash (%)	1.05	10.30	1.84	2.52	1.62	1.52	8.56	4.28	3.05	4.31	3.08	3.37	3.28	10.70
pH	5.12	3.21	4.58	3.95	4.94	4.18	2.95	4.11	3.36	3.72	3.55	3.49	3.56	3.46
Paranitrophenol Content (%)	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30

Table 18. Boot/Shoe Performance Tester Summary Table

LOCATION ON FOOT	Belgian Boot	Canadian Boot	Danish Boot	French Boot	German Ski Boot	German Combat Boot	Greek Boot	Italian Boot	Netherlands Boot	Norwegian Boot (Low Cut)	Norwegian Boot (High Cut)	English Boot (Low Cut)	English Boot (High Cut)	American Boot
Instep	400	700	1005	349	2088	1495	83	810	90	951	307	319	296	648
Inner Ball	260	337	23	1	396	51	55	195	1200	42	206	102	805	781
Big Toe	200	404	23	28	140	99	49	880	590	974	265	140	975	337
Outer Ball	400	850	34	50	1101	101	66	591	760	530	160	20	914	635
Outer Heel	300	583	441	253	2078	179	10	489	3000	20	884	107	139	781
Inner Heel	240	600	157	16	444	33	1500	847	2100	326	882	50	159	415

RESULTS AND DISCUSSION

In general, the boots evaluated were very well constructed and the workmanship was very good. The Item Description sheets and photographs, Figures 3 through 16, illustrate the different design and construction features of the combat boots provided by the NATO countries. Eight of the 14 types of boots evaluated were fabricated with direct molded soles and heels using a vulcanization or injection molding process. These processes do not require the use of nails or stitching to attach the bottom to the boot. The remaining six types of boots were constructed by stitching a strip of welting and midsole to the bottom of the boot. A premolded outsole and heel must then either be cemented, stitched, screwed or nailed to the midsole. For a few types of boots the rigorous use expected dictated that all the above sole attaching mechanisms be used to secure the premolded sole and heel to the welt boot.

Eleven types of boots evaluated were black, while the remaining three types were brown. Considering the emphasis on improved camouflage and the agreement contained in NATO STANAG 2333, it can be projected that more of these boots will be brown in the future.[5] A brown camouflage boot is currently under development in the United States as required by the above listed STANAG.

The chemical analysis of the various types of boots, as summarized in Table 16, provided typical values which one would expect from an evaluation of quality chrome-tanned cattlehide upper leather. The grease content (chloroform soluble matter) of the upper leather was 8 to 15 percent for the boots made with vulcanized or injection molded soles and heels because excess grease will cause poor adhesion between the rubber and the leather. When this was not a factor, such as with welt style boots, the upper leather had grease in excess of 20 percent.

Mildew resistance has been a point of concern to the United States because Military items are subjected to prolonged storage and could be issued in hot, humid environments. After many years of evaluation, paranitrophenol (PNP) was chosen as the most effective mildew inhibitor for leather. During the last 25 years, paranitrophenol has been used in all the leather used for Military footwear in the United States. As the data on paranitrophenol shows, Canada also uses this mildew inhibitor in their footwear. It is our experience that when this mildew preventative treatment is used, mold or mildew does not grow on the leather.

The analysis of the insoles, as summarized in Table 17, shows that vegetable tanned leather was used for the majority of the boots. Some had a chrome retan as illustrated by the presence of chromic oxide. This retan will improve heat resistance, perspiration resistance, dimensional stability and durability. One type of boot did not have a leather insole and this was easily detected by the absence of nitrogen. This element is an essential component in the collagen structure of leather. An examination of the remaining untested portion of the insole showed that it was a neoprene-impregnated, cellulosic insole identified as Texon 437.

[5] NATO Military Standardization Agreement (STANAG) 2333, Performance and Protective Properties of Combat Clothing (16 November 1977).

The Dow Corning flex test results show that only four types of boots evaluated were made with upper leather which could withstand any significant number of flexes before water penetration would occur. The number of flexes required before water penetration could be increased by treating the test samples with Dow Corning leather water resistant resin DC–477.

A number of products were submitted with the various types of boots which were designed to preserve, condition, recolor, and improve the resistance to water penetration. These products were applied to leather samples as directed and demonstrated some advantages. However, none improved the resistance to water penetration when measured on the Dow Corning flexer. Inasmuch as these results showed no improvement in performance they are not present in this report.

As summarized in Table 18, the number of steps required on the Boot/Shoe Performance Tester for water to penetrate into the boot is a function of boot design along with the effectiveness of the water repellent treatment on the leather; in other words, the presence of a high quality leather will not necessarily constitute good results on the Boot/Shoe Performance Tester. The extent of leakage through the needle holes at the stitched seams also drastically influence the results. In general, if a boot leaks in less than 100 steps, it cannot be considered to have any significant resistance to water penetration. If a boot leaks between 100 and 1,000 steps, the level of water resistance becomes more significant with the corresponding increase in value.

The fourteen boots evaluated on the Boot/Shoe Performance Tester gave a wide range of results demonstrating that considerable effort will be required if a more water-resistant boot is considered necessary. The water resistance of the leather will have to be improved, the boot redesigned so as to minimize the seams, and a method developed to prevent water from leaking through the needle holes in the stitching. The main objective should be to increase the resistance to water penetration through the boot from the outside without decreasing the transmission of perspiration in the form of moisture vapor from inside the boot. If a significant level of water resistance is accomplished without any loss in moisture vapor transmission – a most essential parameter for Military footwear – COMFORT will be maintained.